An Architecture for Integrating UMTS and 802.11 WLAN Networks

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Abstract

Cellular networks, e.g. UMTS, provide voice and data services to mobile users. In hot spots where users need high speed data services operators can deploy low-cost high-speed WLANs, e.g. 802.11, to cover hot-spots. This paper proposes a possible architecture of integrating UMTS and 802.11 WLAN. The architecture allows a mobile node to maintain data (PS) connection through WLAN and voice (CS) connection through UMTS in parallel. This is especially attractive because WLAN is currently used primarily for high-speed best-effort data service only.

1 Introduction

The 3G cellular networks, e.g. UMTS [1], are designed to provide voice and data services to mobile users. The sustainable per user data rate is hundreds of kbps limited by the total cell capacity of up to 2-3 Mbps. Multimedia users are known to exhibit asymmetric bandwidth usage behavior, where the download bandwidth is usually two to three order of magnitude higher than the upload bandwidth. Furthermore, the high-speed usage is clustered in certain areas. For example, in Internet cafés, office buildings, and apartment buildings etc. These clusters of high-speed usage areas are called *hot spots*. Fortunately these areas are scattered within a wireless operator's domain. The operators would like to deploy low-cost high-speed solution to cover the hot spots that is either an extension of UMTS or inter-workable with UMTS so that they can use they can maximally utilize the already deployed infrastructure. Wireless LANs, e.g. 802.11[10], offers a viable and attractive choice as being high-speed (up to 54Mbps) and low-cost (hundreds of dollars an AP) for this space. This paper proposes a possible architecture of integrating UMTS and 802.11 WLAN. The architecture allows a mobile node to maintain data (PS) connection through WLAN and voice (CS) connection through UMTS in parallel. This is especially attractive because WLAN is currently used primarily for high-speed best-effort data service only.

For integrating UMTS with WLAN there is more than one point of integration in the UMTS network that may define a workable solution. The applicability of integration architecture depends upon the scenarios it covers. We describe below two usage scenarios.

1.1 Roaming Scenario

In this case WLAN is a standalone network, e.g. deployed in a public space, which is not connected to UMTS network for carrying user traffic. A user may subscribe to UMTS and WLAN network services through the same service provider. If the same operator operates both networks, then it is cost effective for the operator to use a common authentication and billing infrastructure [2].

1.2 Hot-spot Scenario

This scenario emerges when an operator would like to offer high-speed data connection in some hot-spot areas, e.g. within an office building. In this case WLAN is used for data connection only and it operates in conjunction with the UMTS network. The WLAN data service could augment the UMTS packet data service by offering, for example, more bandwidth. Users can use dual-mode terminals to access the two networks. The terminals have two network interfaces – one connects with the UMTS and the other with the WLAN. Figure 1 shows a possible configuration where WLAN forms small (micro) cells within large (macro) UMTS cells. It is possible to use a common authentication and billing infrastructure as well as common connectivity to the Internet.

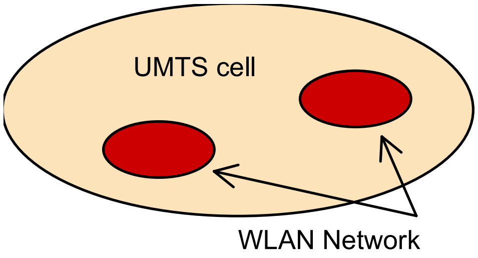

Figure 1: Network Configuration for Hot-spot

This paper is organized as follows. We describe the necessary background about UMTS and WLAN in section 2. We discuss the various possibilities of integrating the two networks with description of our architecture in section 3. This section also describes the proposed terminal model, power-up procedure and the addressing scheme. We discuss resource reservation in section 4. In section 5 we describe mobility

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[*] This work was conducted when the author was affiliated with Wireless Technology Lab at Nortel Networks

management and inter-system handover procedures. The related work is discussed in section 6, and concluding remarks are presented in section 7.

2 Background

In this section we describe UMTS and 802.11 WLAN in necessary detail. We also describe the architecture of 802.11 WLAN network, which is an IP network consists of 802.11 APs supporting mobile routing.

2.1 UMTS and GPRS

The UMTS provides packet data (PS) service for data applications and circuit-switched (CS) service for telephony voice applications. The GPRS network [4], originally designed for GSM, is integrated in UMTS to provide the packet data service. In UMTS, the network of RNCs and Node Bs constitute the radio access network (RAN), called *UTRAN*. The network of one RNC and its Node Bs is called *RNS*. Each Node B constitutes a cluster of base stations and a group of Node Bs is connected to a single RNC. The packet core network (CN) is comprised of SGSN and GGSN. In RAN, the RNC receives downlink packets from the SGSN and converts them into radio frames before sending them to Node Bs. On the reverse path the RNC receives radio frames from Node Bs and converts them into IP packets before sending them to the SGSN. The RNC manages the radio resources of Node Bs and sets up Radio Access Bearers (RABs) through them. The core network is connected to the Internet through GGSN. The SGSN manages mobility states of mobile nodes, establishes the data sessions, and controls the RAB set-up through RNCs. The IP packets are transported through GTP tunnels between GGSN and SGSN, and between SGSN and RNCs. The GTP tunnel uses UDP transport protocol; thus IP is used for packet transport within GPRS.

2.2 IEEE 802.11 WLAN

The IEEE standard 802.11 operates in ad-hoc and infrastructure modes. In infrastructure mode, an Access Point (AP) coordinates the transmission among nodes within its radio coverage area, called service set. We will only describe infrastructure mode in this paper, which is relevant to its integration with cellular network. A Mobile Node (MN) can only associate with one AP at a time. All the MNs associated with an AP communicate with each other either through the AP or directly coordinated by the AP. Roaming across APs is supported in layer-2 through Inter-AP Protocol (IAPP). The APs generate beacons periodically that contain the network-id (or Extended Service Set Identifier, ESSID) and cell-id (which is the AP's MAC address) in addition to other information. On power-up in WLAN the MN associates with the AP by sending associate request frame to the AP. When the MN moves to a new cell where it receives a beacon with the same network-id but a new cell-id, it associates with the new AP by sending re-associate request frame that includes the MAC address of the old AP. The new AP can communicate with the old AP through IAPP [11] to download the context information.

There are two MAC functions that are defined for 802.11 – Distributed Co-ordinate Function (DCF) and Point Co-ordinate Function (PCF). In DCF all the sending nodes compete for the radio channel using CSMA/CA protocol [10]. The node retransmits the frame in case of collision, which is detected by lack of acknowledgement from the receiver. In PCF the AP announces Collision Free Period (CFP) wherein all the MNs back off. The AP polls certain MNs within CFP, which in response transmit the frames The PCF is defined for near isochronous traffic. However, the PCF is not widely implemented in commercial APs.

2.3 IP over 802.11 WLAN

A number of APs can be interconnected through an IP routed network to form the WLAN IP network, as shown in Figure 2. An access router (AR) in the figure connects one or more APs to the network. The APs provide radio interface to the WLAN network, and exchange IP packets with the access routers. They also do ARP proxy for the MNs associated with them. The MN is connected with a single AR at any given point in time, which is called the *serving AR*. The WLAN network is capable of routing IP packets to the serving AR while the MNs move through some form of *mobile routing*.

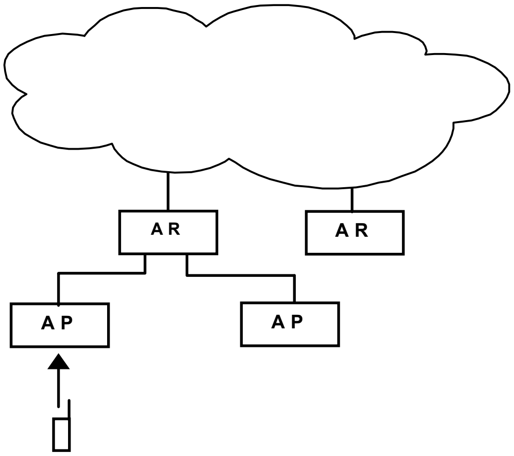

Figure 2: A WLAN IP network

When mobile moves across APs connected through the same AR an *intra-AR handover* takes place. In this case, the AR coordinates and controls the inter-AP handover using IAPP [11]. An *inter-AR handover* takes place when the APs involved in the handover are connected to different ARs. In this case, the new AR interacts with the MN to perform IP handover. It also initiates and participates in the *route repair* process that is the new path set-up inside the network to divert the flow of IP packets destined to the MN to the new AR. For this paper, any intra-domain mobility solution, e.g. Hierarchical Mobile IPv6 [12], CIP [13], M&M [14], together with Fast Handover [15] can be used to perform mobile routing.

We assume IP protocol suite is used within WLAN network. For example, RSVP [16] protocol is used to achieve resource reservation and FHMIPv6 [15] protocol is used to perform handover in the WLAN IP network. Although other protocols for IP network performing above functions can be used to implement our design, these protocols are used to present the ideas in this paper.

3 Integration Architecture

Defining an architecture that integrates the UMTS and 802.11 networks would face the following challenges.

1. What is the impact of differences in QoS models of the two radio access networks on the types of applications users can run and consequently on the traffic handled in each network? The UMTS RNS supports QoS for four well-defined service classes – interactive, voice, stream, and best effort. In contrast, the QoS support for 802.11 is still under discussion in IEEE 802.11f WG, and the CSMA/CA MAC is currently suitable only for best-effort traffic. If PCF is implemented, then it will support near isochronous traffic.

2. How to deal with different connection paradigms used in each network? The GPRS is connection oriented, whereas 802.11 is a connection-less wireless LAN network.

3. How to ensure packet routing across the two networks when different mobility management schemes are employed in each network? In GPRS packets are routed through tunnels established between GGSN-SGSN and SGSN-RNC. In contrast, a number of mobility solutions are proposed for the IP network, which can be used across the IP subnets of an 802.11 WLAN network. Some solutions require establishing tunnels inside the network (e.g. HMIPv6 [12]), whereas others use some form of host-specific routing (e.g. CIP [13], M&M [14]).

4. How to select the best integration point when multiple integration points exist each with different cost-performance benefit for different scenarios? For example, the WLAN can be connected to either RNC, or SGSN, or GGSN.

There is no single integration architecture that is good for all integration scenarios. In the rest of this paper we consider the hot spot scenario and present integration architecture that meet its requirements. For the integration architecture covering roaming scenario see reference [2].

We can establish following requirements for the hot spot scenario:

1. A user in WLAN network can use the 802.11 access for data connection (UMTS PS service) and the UMTS RNS for voice connection (UMTS CS service). He can establish and maintain both connections in parallel, but he cannot use UTRAN access for PS service.

2. The user can augment the data service while connected to WLAN network, which consequently allows him to run some applications that he cannot run otherwise (that is while connected only to UMTS network).

3. The user in UMTS network use UMTS RNS for both PS and CS services.

The fundamental idea behind our integration architecture supporting hot spot scenario is that a MN when moves to the 802.11 micro cell, the PS connection (connection for packet data service) through the UMTS RNS (or effectively through GPRS) is dismantled and it is re-established through the WLAN network. Inside the 802.11 cells the MN can use UMTS RNS for CS connection (connection for voice service). Thus the design assumes that a MN is a dual-mode terminal with two interfaces – one is UMTS interface and the other is 802.11 interface. The two interfaces can be active at the same time. Figure 3 shows the proposed architecture where SGSN is the integration point. For the SGSN, WLAN and UTRAN are two different types of radio access networks.

Let us evaluate the other two options before discussing the integration at SGSN. The RNC performs radio specific tasks, such as it converts packets into radio frames and vice versa, manages the radio resources, and controls handover etc. Connecting the WLAN at RNC requires major revision of complex radio procedures implemented at RNC because the two radio interfaces are totally different. Alternatively, the WLAN can be connected at GGSN that seems to simplify the handover from UMTS to WLAN because the GGSN only maintains session contexts for PS connections. But in this case during handover to UMTS the SGSN needs to recreate the mobility state, and acquire or re-establish the session (PDP) and RAB contexts; these are the information that the GGSN does not have, hence the handover would be slow.

The integration architecture depicted in Figure 3 shows that the WLAN network is connected through border routers (BRs) to SGSN. A connection through UMTS network requires explicit signaling between the MN and the network to establish and manage the bearer path. The MN in 802.11 cells can maintain connectivity to WLAN network and UMTS through different interfaces. The UMTS connection is only used for voice service. This connection can also be used for PS signaling – that is to establish and manage the PS connection. Hence, the existing GPRS signaling protocol, e.g. PDP context, can be used for establishing bearer data path through WLAN network. But it needs significant changes in most of the GPRS procedures implemented at SGSN to distinguish the two cases where PS bearer paths are set-up through either UMTS RNS or WLAN. In another approach, which is adopted for this architecture, both bearer and signaling paths for PS connections are established through WLAN to the SGSN. This requires small changes in some of the existing GPRS procedures. Since the voice connection has an independent signaling and bearer path with no bearing on the data connection, we will not discuss it further in the paper.

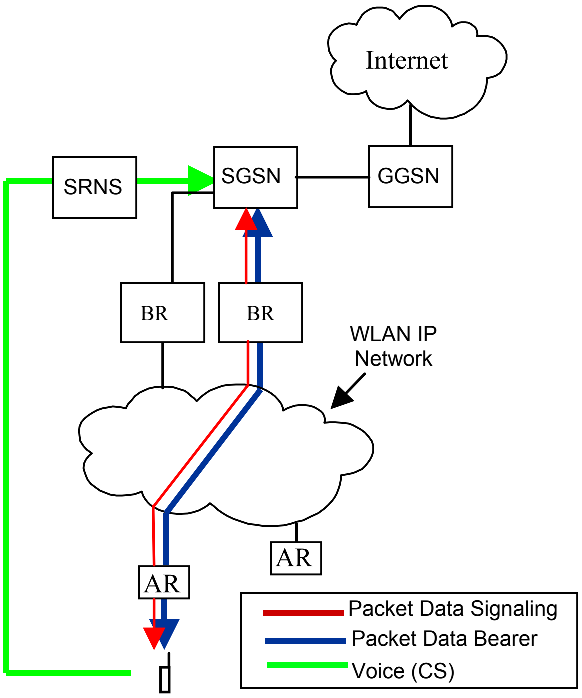

Figure 3: Integration Architecture

3.1 Terminal Model

In this paper we assume that the user terminal is equipped with two interfaces – one is the UMTS interface and the other one is the 802.11 interface. Both interfaces can be enabled at the same time for providing connectivity to their respective networks.

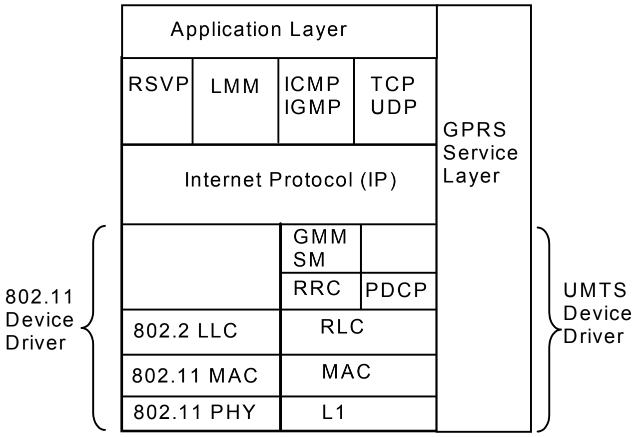

Figure 4: Terminal stack

Figure 4 shows the proposed stack architecture that is capable of supporting multiple interfaces. This architecture conceptually follows the Internet layer model. The 802.11 device driver contains IEEE 802.2 LLC and 802.11 MAC control functions. The UMTS device driver implements the UMTS user and control plane functions. For example, the GPRS-specific part of the device driver, shown in Figure 4, contains the implementation of GPRS protocols below IP layer of the GPRS user plane protocol stack. It also includes the control plane protocols such as GMM/SM for mobility and session management and RRC for radio resource control [1]. The GPRS service layer is introduced to provide interaction of higher layers with the GPRS protocol stack. We assume that the IP protocols suite contains RSVP for QoS signaling and resource reservation, and a mobility management protocol for local mobility management (LMM) in the WLAN network. The LMM implements any local mobility management protocol, e.g. HMIPv6 [12] with Fast Handover [15]. The applications interact with the stack using standard RSVP API. The API implementation uses either RSVP or PDP context signaling depending upon whether the session is established through the WLAN or UMTS network. It however maintains single QoS state for each session. The protocol blocks keep the protocol specific states, for example RSVP block maintains the RSVP states and the GMM/SM block maintains the PDP contexts.

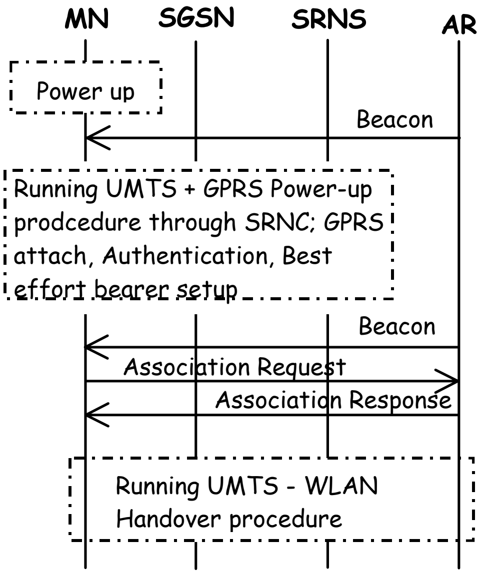

Figure 5: Power up procedure

3.2 Power up

When a mobile node is powered up in a UMTS cell it only receives beacons from the UMTS base station, hence it activates the UMTS interface and runs the UMTS power up procedure. If it is powered up in an 802.11 cell it can be connected to both UMTS and WLAN networks. In this case, it receives beacons from the UMTS base station as well as the 802.11 AP. Since UMTS provides the basic wireless service, the node runs the UMTS-GPRS power up procedure through the UMTS interface. During power up it ignores the 802.11 beacons received by the 802.11 interface. Figure 5 shows the power up procedure. On power up it attaches to GPRS and establishes the basic PS connection through the SRNS with the SGSN and GGSN. The basic PS connection sets up only best-effort bearer service. The PDP context is established at the GGSN, the SGSN and the MN, whereas the mobility context is established at the SGSN and the MN. The SRNS performs RAB set up for the best-effort bearer service.

After performing the UMTS power-up procedure, the node responds to the 802.11 beacons by running the association procedure with the AP. Once it is associated with the AP, it runs the UMTS-WLAN handover procedure described in Section 5 to handover the basic PS connection to the WLAN network. In the discussion below we consider the MN is attached to the GPRS network.

3.3 Addressing Scheme

In UMTS the mobile node is assigned an IP address by the GGSN (or at the GGSN in case of MN using IPv6 autoconfiguration). The MN uses that address to communicate with the nodes in the Internet. In our integration architecture the GGSN remains the gateway to the Internet. Hence, the MN can use the same IP address that it receives from the GGSN while connected to UMTS during power-up inside the WLAN network to communicate with the nodes in the Internet. Since that IP address is not guaranteed to be topologically correct address in the WLAN network, the MN can acquire a temporary topologically correct address, called care-of-address (COA) in the WLAN network that can be used as the tunnel end point for the packets tunneled between the SGSN and the mobile node. The detail of how the COA is used in handling mobility depends upon the mobility solution. The detail can be seen in [12, 17].

4 Resource Reservation

The GPRS is a connection-oriented network where PS sessions are established prior to communication between the MN and the nodes in the Internet. For every PS session a GGSN-SGSN and SGSN-MN connections are established. The PDP context signaling is used to set up the connection and reserve resources in the GPRS packet network. The RAB signaling is used between SGSN and RNC to set up the radio channels and reserve radio resources. The upper box in Figure 6 shows an example of PDP context set up invoked by the MN; see [1] for the detail of PDP context procedures. In this case, the MN communicates with the SGSN to initiate PDP context set up. The SGSN coordinates the PDP context set up with the GGSN and the RAB set up with the SRNC. It sends *Create PDP Context* (CPC) request message to the GGSN, and after receiving the response sets up the RAB through the SRNC and then sends the final response to the MN.

The communication path for the MN in the WLAN network has two segments – one in the GPRS network and the other in the WLAN network. The SGSN to BR connectivity is considered as a part of UMTS-GPRS network. The GPRS path requires PDP context set up for all the data sessions established from within the WLAN network. The WLAN IP network can use either IntServ or DiffServ QoS models. Like PDP context the IntServ requires a connection to be established between the MN and BR for any QoS guarantee to be made for the packets in the WLAN network. In case of the DiffServ-based WLAN network no explicit connection is required in the network. The discussion on the suitable model for the WLAN network is outside the scope of this paper. However, the idea presented here is designed to work for both models.

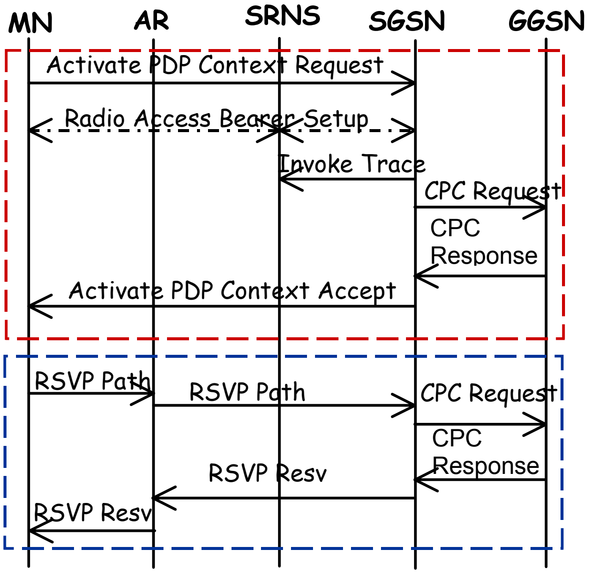

Figure 6: Resource Reservation Procedure

In the WLAN network, RSVP can be used for the network resource reservation. The MN sends RSVP PATH message to the SGSN for establishing a new data session, which initiates the corresponding PDP context set up within GPRS. A GPRS-attached mobile node keeps the address of the SGSN in its mobility context. The session parameters in the RSVP PATH message contain the parameters defined for UMTS services. As shown in the lower box of Figure 6, the SGSN negotiates the session set up with the GGSN using PDP context messages. It responds with RSVP RESV message to the MN.

The RSVP messages can be intercepted and processed within the WLAN network for QoS provisioning by deploying RSVP-aware routers in the network. For DiffServ provisioning only edge routers need to be RSVP-aware. For example, the AR is the intermediate RSVP-aware router that intercepts and processes the RSVP messages exchanged between the SGSN and MN. To handle mobility while RSVP session is in progress the AR is anchored until it receives and forwards the RESV message. If the WLAN network employs the IntServ QoS model, then more routers will be RSVP-aware using RSVP to set up resources along the path from the MN to BR. Handling mobility is more complicated and it incurs significant overhead because the reservation needs to be torn down along the old path-segment and set up along the new path-segment after the MN moved to the new AR.

With no QoS support in existing 802.11 implementations the 802.11 is mainly used for best-effort service, which requires no exchange of signaling between the MN and AR for bearer set up. When the QoS will be supported, then separate RSVP sessions can be established between the SGSN and AR for the radio resource allocation at 802.11 APs. The SGSN can establish a new RSVP session with the AR for radio bearer set up in the 802.11 cell. It sends RSVP PATH message to the AR before sending the RESV to the MN. The AR performs radio resource allocation and responds with the RESV message to the SGSN. Then, the SGSN sends the final response in the RESV message to the MN. The final response is affected by the result of reservation of the resources inside the GPRS and the WLAN including the 802.11 radio resources.

5 Mobility and Handover

The mobility context in GPRS related to the MN's movement within the UMTS network is stored at both the SGSN and the node itself, which we call *GPRS mobility context*. The MN and some nodes in the WLAN network, e.g. access routers, maintain mobility context related to the node's movement within WLAN, which we call *WLAN mobility context*. Thus, the MN maintains two mobility contexts – GPRS and WLAN mobility contexts.

The GPRS mobility context does not keep the detailed state information related to the node's mobility within WLAN. Rather it maintains a single additional state corresponding to the node's connectivity to WLAN. In Figure 7 the GPRS MM context contains the three GPRS states denoted by the PMM label and the WMM-connected state. The context is maintained at both the MN and the SGSN. When the MN is attached to the GPRS network, it is in the PMM-connected state. In the power-saving mode it transits to the PMM-idle state and releases the radio resources. Paging is used to establish the radio link connection before the packets are forwarded to the MN in this state. In this state if the MN moves to WLAN, it follows the inter-system handover procedure described in Section 3.1 and transits to WMM-connected state The PMM-detached is the power-down state. The WMM-connected state reflects the situation when the mobile is connected to WLAN.

The power-up scheme described in Section 3.2 requires MN to power-up through UMTS interface. Hence, the MN transits from PMM-detached to PMM-connected state during power-up before making handover to WLAN. After becoming associated with an 802.11 AP the MN transits to the WMM-connected state. The transition from the PMM-connected to WMM-connected state occurs as a result of inter-system handover that is carried out using the inter-system handover procedure. The MN remains in the WMM-connected state for as long as it is connected with WLAN.

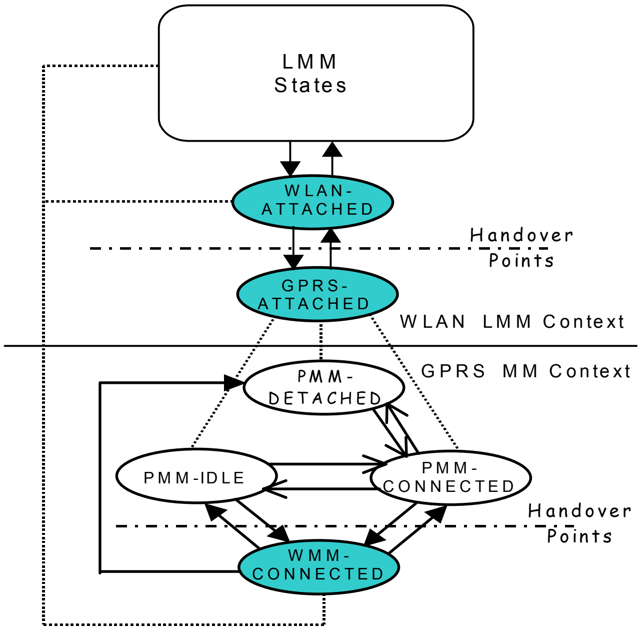

Figure 7: Mobility state maintained by SGSN and MN.

The WLAN LMM context, as shown in Figure 7, contains the detailed states related to the MN's mobility within WLAN. It also contains two additional states—GPRS-attached and WLAN-attached states. The former shows that the MN is no longer connected to WLAN. The transition from GPRS to WLAN attached state occurs as a result of inter-system handover from UMTS to WLAN. Figure 7 shows the integration of WLAN LMM and GPRS MM contexts. The dotted lines in the figure show the correspondence between the states in the two contexts. For example, when the MN is in any LMM state it is shown to be in the WMM-connected state in the GPRS MM context.

The MN can change to power-saving mode within 802.11 WLAN. Unlike UMTS, the 802.11 support for power saving requires the MN to associate with the new AP when it moves from the coverage area of one AP to another. Once the AP knows that the MN is in the power-saving mode it polls the MN by sending TIM in the beacon whenever it has a packet for the MN to transmit [10]. The MN responds the poll and requests for the subsequent transmission of the packets. The packet routing system within the WLAN network is always able to keep track of the serving AR when it is ready to forward the packets from the SGSN even when the MN is in the power-saving mode. Hence, there is no need to maintain additional state in the GPRS mobility context corresponding to the MN's power-saving mode in WLAN. The SGSN sends the downlink packets to the MN when it is in WMM-connected state. When the power-saving MN moves to UMTS it can transit from WMM-connected to PMM-idle state.

5.1 Inter-System Handover

The WLAN APs periodically transmit beacons, which are received by all powered up MN roaming within the AP coverage area even those that are in power saving mode. The MN detects the inters-system handover condition by receiving beacons from the first 802.11 cell after moving to WLAN. It performs the UMTS-WLAN inter-system handover procedure, as shown in Figure 8. First, it performs the association-handshake with the AP to establish layer-2 connectivity. The AP generates a trigger to AR after issuing association response to the MN. The trigger causes AR to immediately unicast Router Advertisement (RA) to the MN. The trigger expedites the layer-3 handover process, as the AR in this case need not wait for Router Solicitation (RS) from the MN before sending out RA. It also saves an over-the-air messaging, i.e. RS.

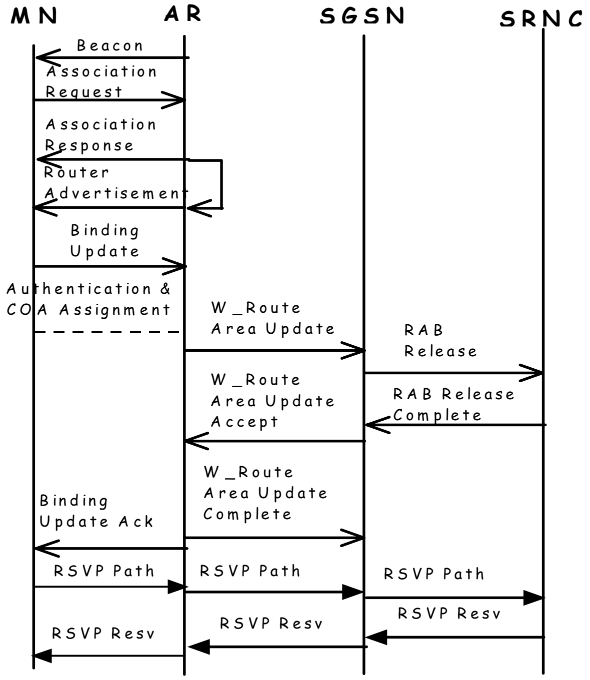

Figure 8: UMTS-WLAN Handover procedure

Next the MN performs layer-3 (IP) handover. The RA contains pertinent information about the AR, e.g. its IP address etc, which are used by the MN to perform the Binding Update (BU) procedure with the AR [15]. The BU message contains the SGSN address and other UMTS-specific information to identify the mobile node and its mobility context in the SGSN. As a result of receiving BU message, the AR authenticates the MN with the AAA server and makes the care-of-address (COA) assignment.

After authentication and COA assignment, the AR initiates the handover procedure with the SGSN by sending W_Route Area Update message. Before acknowledging the update message, the SGSN first sends RAB release message to the SRNC to tear down the radio access bearers used by the UMTS packet data service. The SRNC releases the radio resources and the channels for the packet data service and then sends RAB release complete message to the SGSN. Then, the SGSN sends W_Route Area Update Accept message to the AR. It also changes the MN's GPRS mobility state to WMM-connected state.

In the W_Route Area Update Accept message the SGSN includes the list of PDP contexts and the context from SRNC. These contexts remain opaque to the AR, which simply includes them in the Binding Update Acknowledgment (BU Ack) message to the MN. The AR first completes the handover with the SGSN by sending W_Route Area Update Complete message, and then sends BU Ack to the MN to signal the completion of the inter-system handover from UMTS-WLAN.

The MN after receiving the BU Ack message can initiate the resource reservation for the PDP connections inside WLAN. It can selectively reserve resources for some PDP connections and teardown others. Thus, all the remaining PDP contexts will have a corresponding RSVP state at both the MN and the SGSN.

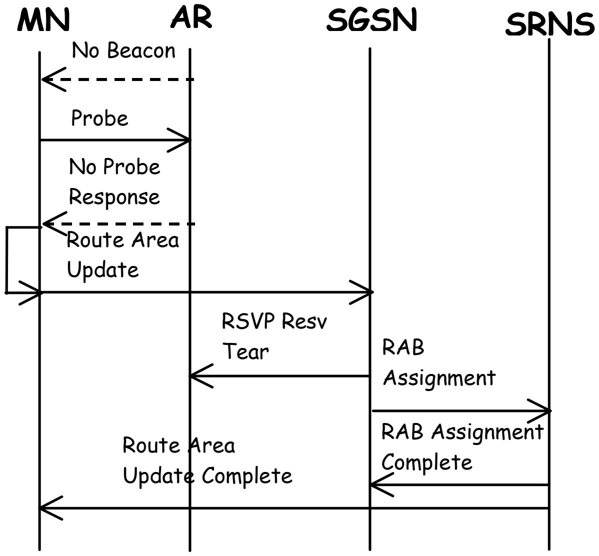

Figure 9: WLAN-UMTS Handover Procedure

When the MN moves out of the WLAN its 802.11 interface detects missing beacons. It then attempts to detect the AP by sending probe. Failing to receive probe response indicates the handover condition from WLAN to UMTS. Figure 9 shows the WLAN-UMTS handover procedure. The MN sends Route Area Update message to SGSN through its UMTS interface including information that indicates that it is disconnected to the WLAN network. The message includes the IP address of the last AR it was attached with. The SGSN sends RSVP RESV TEAR message to the AR, which causes it to release the resources assigned to the MN.

6 Related Work

Most of the integration architectures proposed in literature support roaming service [2,5]. The IST Wineglass architecture

[5,8] connects the UMTS and 802.11 WLAN networks through an IPv6 backbone network. It proposes a major change in UMTS of replacing the GPRS core network by a UTRAN IP-Gateway. Another architecture proposed in [2] for roaming scenario allows a mobile operator to offer both UMTS and public-WLAN access services. The operator can use the UMTS authentication and accounting infrastructure for both access networks. The mobile user data can be stored in SIM card, which is used by the mobile node in WLAN to get authenticated through the UMTS core network. A qualitative comparison is presented in [9] that evaluates two points of integration of UMTS with WLAN – RNC and SGSN. The study concludes that the SGSN-based integration requires: 1) RNC counter part function in the WLAN network; 2) Handover control function in the MN and RNC; and 3) UMTS QoS functions within WLAN network. A similar comparison can be found in [7]. We have identified similar issues and present a design that provides an effective solution for them. In [3] a detailed discussion on integrating several wireless access technologies in general is presented. The tight-coupling architecture between GPRS and 802.11 WLAN presented in [18] has many common features with our architecture. For example, it allows GPRS service continuity in WLAN, and integrates WLAN at SGSN. The architecture proposed in [18] incorporates an interworking gateway (GIF) in WLAN network that performs Wireless Adaptation Function (WAF). For example, signal translation, QoS parameter exchange, route discovery between the GPRS and 802.11 MAC. The WAF is a sub-layer defined below IP layer. The notable difference between our approach and the architecture proposed in [18] is that we propose integration at IP layer, which gives us the flexibility of using the IP suite of protocols in WLAN. The WAF implementation constrains the size of WLAN network to a single subnet connecting few APs (up to 3). In contrast, our architecture supports an IP network of APs running mobile routing. Finally, unlike GIF our network does not contain a single interworking gateway function causing single point of failure in low-cost WLAN network.

7 Concluding Remarks

In this paper we presented integration architecture for UMTS and WLAN. The WLANs in hot-spot areas form micro-cells within UMTS macro-cells. The architecture allows a mobile node to maintain data (PS) connection through WLAN and telephony voice (CS) connection through UMTS in parallel. This is especially attractive because WLAN is currently used primarily for high-speed best-effort data service. We also proposed a terminal architecture that incorporates both UMTS and 802.11 interfaces. It isolates UMTS-specific protocol stack in the device driver block, and gives full IP protocol capability to 802.11 connections. We presented a scheme for establishing PDP context and resource reservation when the mobile is connected to WLAN. We also presented inter-system handover in sufficient detail, which works with a variety of micro-mobility solutions used in WLAN network. In future, we would like to review the resource reservation by considering the 802.11 QoS and it radio resource management.

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